Accident risk of foreign drivers in various road environments

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Abstract

(a) Introduction: This paper reports a study on the accident risk of foreign and native drivers in various road environments in Greece. In particular, the analysis aims to determine the combined effect of driver nationality, area type (inside/outside urban area), junction (yes/no) and lighting conditions (day/night) on accident fault risk.

(b) Methods: Data from the national accident database of Greece are used in a hierarchical log-linear analysis. The induced exposure technique is applied due to the lack of exposure data. Estimated and observed odds ratios are then examined for the quantification of the various effects in terms of relative risk.

(c) Results: The initial examination of a saturated model leads to the rejection of all three- and higher-order effects within variables, without providing an adequate fit to the data. On the contrary, a non-saturated second-order model presents a very satisfactory overall fit. The examination of single and combined effects indicates that the most significant effect on accident risk rises from the presence of foreign drivers at junctions.

(d) Conclusions: Results confirm that foreign drivers in Greece are at increased risk. However, immigrant permanent residents appear to have a lower risk compared to tourists regardless of the road environment.

Key words: driver nationality, road characteristics, accident fault risk, induced exposure, log-linear analysis

1. Introduction

A poor knowledge of the road network, a lack of understanding of local traffic rules and insufficient driving skills under unknown conditions may result in an increased accident involvement, severity and risk of foreign drivers. A variance of the general attitudes towards road safety, which are reflected in the driving behavior, may further contribute to a higher accident risk of foreign drivers, compared to the natives'.

The effect of driver's nationality on road safety parameters is widely examined in the literature in the framework of macroscopic cross-national road safety studies, which may range from accident frequency and severity comparisons (European Commission, 2003, ETSC, 2003) to studies on road safety attitude and driver behavior (Asai et al. 1980, SARTRE 2004) and drivers perception investigations (Al-Madani, Al-janahi, 2002). These studies mainly concern comparisons between countries; they are in most cases based on national road accidents and fatalities statistics and provide little or no information on accident risk.

Few studies focus on road safety issues of foreign and native drivers in the same country. In particular, in a study on driver behavior-in-motion (Koushki et al., 1998) relating seat belt use with other factors such as nationality, age, gender, road type, vehicle type, trip time and distance, discriminant analysis is applied to discriminate between high and low traffic violations rates. Results indicated that foreign drivers have higher seat belt use rates and lower traffic violations rates. Another study investigated risk-taking proneness among various Spanish and U.S drivers' categories by examining intersection gap acceptance, and found no significant differences among different nationalities (Soler, Sivak, 1987). Aty and Radwan (1998) used log-linear models to investigate the role of demographic factors on the relative risk of accident involvement and severity at intersections and found that foreign drivers have higher accident rates at intersections with turning maneuvers. Finally, Quddus et al. (2002) used ordered probit models to examine factors that affect injury severity in motorcycle accidents and found that foreign drivers have increased probability of severe injury.

A study in the Greek island of Corfu (Petridou et al., 1999), examines whether traffic injuries among tourists are more common and severe. Based on hospital data, the study concludes that tourists are at increased risk of traffic injuries in comparison with Greek drivers. Another relevant study (Petridou et al., 1997) dealing with road traffic accidents and pleasure traveling in the Greek island of Crete suggests that foreign drivers from left-side driving countries had an increased risk of traffic accidents (2.5 times more than those from right-side driving countries) especially when they drove a rented rather than an owned car.

Another study investigates the behavior of American drivers in Europe resulting from the different signing policy at uncontrolled intersections (Summala, 1998). Due to the different signing policy and priority rules between US and Europe it was found that American drivers tend to adopt more risk-taking crossing behavior, however a change of strategy was observed when they were informed about the general rule. A similar study (Dissanayake, Lu, 2001) dealing with the understanding of traffic control device by tourists claims that most international drivers lack understanding of traffic signs, markings and traffic signal indications in relation to the natives. The accident risk of Russian drivers in southeastern Finland is examined in another study, (Leviakangas, 1998), in which a higher accident risk of foreign (Russian) drivers in comparison with native (Finnish) drivers is identified. The seasonal distribution of accident occurrence is also examined, representing the role of increased hazards of the road network in winter conditions.

According to the above results, foreign drivers, bringing their own rules and practices to an unfamiliar environment, appear to be at increased accident and injury involvement and / or risk. Various demographic and behavioral parameters may account for this phenomenon and should be investigated in order to suggest information policies to smoothen relevant inconsistencies. Moreover, it is necessary to further investigate and quantify the role of specific features of the environment and the infrastructure, allowing for specific design and signalization interventions to promote the road safety of foreign drivers. Additionally, it would be important to distinguish the different types of foreign users of the road infrastructure i.e. examine separately a country's immigrant and tourists population. Finally, investigation should further focus on accident risk (rather than accident frequency) and deal with the methodological difficulties involved.

2. Objectives, data and methodology

2.1. Objectives

This research aims to investigate the accident risk of foreign drivers in Greece in relation to roadway environment. In particular, the analysis seeks to examine the extent to which the probability of accident involvement of foreign drivers (immigrants or tourists) in accidents is disproportionally high compared to the natives' and determine the role of various infrastructure parameters. The results could then be exploited for the promotion of appropriate measures, adapted to the specific needs of each category of foreign drivers, for the improvement of their road safety and comfort.

Greece is chosen as a representative example of a country accommodating foreign drivers of different types. In particular, a considerable increase to the immigrants' population of Greece, (167,000 in the 1991 census to 800,000 in 2001), mainly Albanians, added to the native population as permanent residents during the decade of 90's, as well as its popularity as a tourist destination, have subsequently led to the increase of the Greek road network users. It can be considered that four main subcategories of drivers are representative of the population composition in Greece: Greek drivers, Albanian drivers, who constitute the majority of immigrants permanent residents, drivers from EU countries (taken the EU of 15 member states), who constitute the majority of tourists and visitors in Greece, and drivers of other (than Greek, Albanian or EU) nationality, who include both permanent residents and tourists.

In Table 1, the frequencies of accidents involving foreign persons and the frequencies of foreign persons killed in road accidents in Greece for the years 1985-2000, show a steadily increasing trend which becomes more apparent during the decade of 90's. The number of foreign drivers killed in particular exceeds one hundred for the first time in 1997, i.e. at the end of a period that could be described as transitory, as the first immigrants who arrived in Greece back in the early 90's could not afford car ownership. In addition, the period from 1997-2000 sums over 40% of the total foreign drivers killed. Thus a first assumption may attribute the phenomenon to the above-mentioned flood of immigrants. Unfortunately the lack of time exposure data that could show clearly the hazardous drivers' subcategories is impeding the identification of potential determinants.

Table1 to be inserted here

Moreover, the proportion of foreign persons' accidents inside urban areas increased from around 50% in the late 80's to 67% in 2000, while the respective proportion of accidents at junctions increased from 43% in 1996 to 52% in 2000. Around 38% of the yearly foreign person's accidents take place during the night, with no important variation within the period 1985-2000. It is also interesting to note that around 48% of the yearly foreign fatalities concern drivers, 32% concern passengers and 20% concern pedestrians, and these proportions present no significant variation within the examined period. Furthermore, around 65% of yearly foreign fatalities concern persons of age <35 years.

According to the above, it is interesting to investigate whether foreign drivers bear a higher accident risk compared to the natives, and whether accident risk varies among different categories of foreign drivers and /or among different road environments. Other parameters of foreign drivers' behavior, such as speeding or involvement of alcohol would be interesting; however no reliable relevant data is currently available in Greece.

The parameter of road environment is of particular importance, for a number of reasons: firstly, the diversities of the Greek relief often result in a more complex road alignment (e.g. increased gradients and frequent curves), that some foreign drivers may be less familiar with. Secondly, deficiencies in the construction and poor maintenance, which are often observed on the Greek road network, may also be a "surprise" for foreign drivers. And finally, specific particularities of signing, signalization and road markings of the Greek road network may differ from respective settings in other countries and complicate thus the driving task for foreign drivers.

Moreover, improving the Greek road environment to better meet the needs of foreign drivers would be a straightforward and efficient way for dealing with these needs. On the contrary, dealing with the effects of personal characteristics of foreign drivers (e.g. age, gender, experience) would involve particular measures (e.g. training), whose implementation would be complex, if not unfeasible. For all these reasons, the present analysis focuses on the effects of road environment.

For this purpose, a log-linear modeling technique is applied in order to analyze the aggregate data describing the cross-classification of accident risk, driver's nationality and type of road environment, and to identify significant interactions among these effects. An induced exposure technique is used to overcome the lack of relevant exposure data.

2.2. Dataset

Data from the National Accident database of Greece are used in this research. This database includes all injury accidents, the related casualties and the drivers involved for the period 1985-2001 as reported by the police. The dataset used in this research includes all drivers reported to be involved in an injury accident for the period 1996-2001, cross-classified by driver's nationality, inside and outside urban areas, at or not at junctions and during daylight or night, these above characteristics being chosen as the most critical for the determination of road accident risk in terms of road infrastructure. It should be noted that daylight is defined as the period starting half hour before sunrise and finishing half hour after sunset. Moreover, an accident is considered to be "at junction" when it took place at a distance less than 12m from a junction.

Four categories of drivers are examined, as explained above: Greek drivers, Albanian drivers, drivers from EU countries (taken the EU of 15 member states), and drivers of other (than Greek, Albanian or EU) nationality.

The data input comes from the National Statistical Service of Greece, which has as original source the Road Accident Data Collection Form, a form describing analytically the conditions of each accident. As part of the reporting procedure, the driver's nationality is checked by his driving license, so there is no evident reason for reporting problems as far as driver's nationality is concerned. It should be also noted that no important reporting deficiencies are expected as far as the road infrastructure variables are concerned; previous research has shown that accidents reporting problems in Greece are encountered only for specific variables (e.g. use of safety equipment, driving under the influence of alcohol, accident location etc.) (NTUA/DTPE, 2002).

2.3. The induced exposure technique

The quasi-induced method of measuring exposure has been widely examined in international literature and was found to be promising, under certain conditions, for determining relative at-fault accident rates in which not-at-fault accidents serve as an indicator of exposure. The approach relies on the assumption that the "innocent victim" in two-vehicle accidents represents a random sample of the driver-vehicle combinations that are present on the roadway system under specified conditions (Haight, 1973, Golias, Yannis, 2001).

The induced exposure technique is based on the assumption that in every road accident in which two vehicles are involved there is one driver responsible for the accident and one innocent driver involved selected at random from the total population of drivers. Consequently, the innocent driver can be considered as a sample of the total population of drivers and reflects the exposure of any specific driver population defined on the basis of certain characteristics (Haight, 1973, Hodge, Richardson, 1985, Koornstra, 1973). The basic requirement for the use of this method is the identification of the driver who provoked the accident. Additionally, the use of the method in other than two-vehicle accidents is not recommended (Evans 1990).

In theory, one of the most important feature of this technique is the fact that it allows for disaggregate analysis to the level of disaggregation of the accident data (Golias, Yannis, 2001). However, this feature has not been used in the existing research, primarily due to the difficulties in the interpretation and classification of the detailed accident rates. In particular, relative accident risk rates are meant to correspond to categories of drivers of different characteristics. However, the risk attribution to categories of a single variable is quite straightforward, whereas accident rates of driver categories resulting from the combination of different variables (dissagregation) are more complex and less directly comparable.

It should be noted that the induced exposure technique in Greece was recently successfully validated for a number of user and vehicle categories by means of exposure data collected through a nationwide travel survey (NTUA/DTPE, 2005). However, previous research in Greece has shown some bias in the assertion of accident fault per vehicle category by the Police, in favour of the lighter vehicle (Yannis et al., 2005). Therefore, only accidents between passenger cars are examined in the present research.

In order to further validate the suitability of the "innocent drivers" distribution as a measure of exposure by driver's nationality, an additional test was carried out. In particular, the "innocent drivers" distribution by nationality was calculated for three different options: when the ‘at-fault driver' was Greek, when the ‘at-fault driver' was Albanian and when the ‘at-fault driver' was an EU-national. Results are presented in Table 2.

Table 2 to be inserted here

It is interesting to note that no significant differences among the three ‘innocent driver’ distributions are observed; in particular, the 'innocent' drivers distributions are practically equal between Greek and Albanian 'at-fault' drivers, whereas only slight differences are obtained for EU ‘at-fault' drivers. The three distributions were further compared by means of the Kruscal-Wallis non-parametric test. The non significant Chi-square value obtained (3.5 for 2 degrees of freedom, probability= 0.174) led to the rejection of the hypothesis that the three distributions are different, allowing to assume that the three 'innocent' drivers samples come from the same population. Consequently, no significant bias by driver nationality is observed in the assertion of accident fault by the Police and therefore the ‘innocent drivers’ distribution is suitable as a measure of exposure by nationality.

2.4. Log-linear models for the analysis of multi-dimensional Tables

This research aims to associate accident fault risk with driver nationality and roadway environment. The analysis seeks to investigate the various combined effects of driver nationality and area type, junction and lighting conditions on accident risk. Therefore, no direct conclusions can be extracted through the calculation of accident rates, especially when effects are examined separately. In order to determine the significance of all possible interactions, the analysis of a five-dimensional Table through a log-linear modelling approach was attempted.

A five-dimensional Table of i rows, j columns and k, l, m layers can be decomposed in row effects, column effects, layers effects and their interactions:

Simple	i, j. k, l, m
First order	i×j, i×k, i×l, i×m, j×k, j×l, j×m, k×l, k×m, l×m
Second order	i×j×k, i×j×l, i×j×m, i×k×l, i×k×m, j×k×l, j×l×m, k×l×m,
Third order	i×j×k×l, i×j×k×m, j×k×l×m, i×k×l×m, i×j×l×m
Fourth order	i×j×k×l×m

In the framework of the present research, the fourth-order interaction (i×j×k×l×m) is the most interesting since, if this effect is significant, then there is a significant interaction of driver nationality and all the examined roadway characteristics with regard to accident at-fault risk. If (and only if) not, then the various lower-order effects can be further analysed and interpreted (Goodman, 1973).

The log-linear analysis uses an additive model that incorporates main effects and interactions between variables (1: accident fault, 2: driver nationality, 3: area type, 4: junction and 5: lighting conditions) in the following form:

$$\begin{aligned}\text{Log } F_{ijklm} = {} & u + u_{1(i)} + u_{2(j)} + u_{3(k)} + u_{4(l)} + u_{5(m)} + u_{12(ij)} + u_{13(ik)} + u_{14(il)} + u_{15(im)} + u_{23(jk)} + \\ & u_{24(jl)} + u_{25(jm)} + u_{34(kl)} + u_{35(km)} + u_{45(lm)} + u_{123(ijk)} + u_{124(ijl)} + u_{125(ijm)} + \\ & u_{134(ikl)} + u_{135(ikm)} + u_{145(ilm)} + u_{234(jkl)} + u_{235(jkm)} + u_{245(jlm)} + u_{345(klm)} + \\ & u_{1234(ijkl)} + u_{1235(ijkm)} + u_{2345(jklm)} + u_{1345(iklm)} + u_{1245(ijlm)} + u_{12345(ijklm)}\end{aligned}$$

Where F_{ijklm} are the expected cell frequencies and u are parameters to be estimated. The above formula for a five-dimensional Table corresponds to a saturated log-linear model, containing all possible four- and lower order effects. Moreover, it should be underlined that the models considered are hierarchical, meaning that whenever a higher order effect is included in the model, the lower order effects composed from variables in the higher effect are also included (Everitt, 1977, Kim et al., 1998).

The hypotheses of the analysis are those of mutual independence, which specifies that there are no associations of any kind between the five variables, or in other words that there are no first-order interactions between any pair of variables and no conjoint three-, four- and five-variable interaction:

H_0: $u = u_1 = u_2 = u_3 = u_4 = u_5 = u_{12} = u_{13} = u_{14} = u_{15} = u_{23} = u_{24} = u_{25} = u_{34} = u_{35} = u_{45} = u_{123} = u_{124} = u_{125} = u_{134} = u_{135} = u_{145} = u_{234} = u_{235} = u_{245} = u_{345} = u_{1234} = u_{1235} = u_{2345} = u_{1345} = u_{1245} = u_{12345} = 0$

Main effect parameters are measured as deviations of row, column or layer means of log-frequencies from the overall mean. Each of the u parameters represents a deviation from the grand mean due to that effect (Hays, 1981). For example, $u_{2(j)}$ are nationality effects with a separate parameter estimate for each nationality group. The term $u_{23(jk)}$ represents the interaction between driver nationality and area type, with a separate parameter estimate for each pair of categories. Estimates of the parameters in the fitted model are obtained as functions of the logarithms of cell frequencies and the form of such estimates is very similar to those used for the parameters in analysis of variance models. It should be noted though that no dependent variable in the usual sense is designated in a log-linear model, as all variables are "factors" classifying the observations according to a group in which they belong; there is no "response" variable classifying according to a description of what happens during or after an experiment (Everitt, 1977).

From the best-fitting log-linear model, the parameter estimates and their statistical significance are determined. The ultimate test is whether the Table generated by the model closely fits the observed Table. A likelihood ratio goodness-of-fit statistic is used to accept or reject the model (Everitt, 1977).

3. Results

3.1. Relative accident risk of foreign and native drivers

Accident fault risk rates were calculated on the basis of driver's fault frequencies under the induced exposure assumptions. It should be noted that all sub-categories included an adequate number of cases (i.e. no less than 30) out of approximately 34,000 cases. In Table 3, the relative accident fault rates are presented, derived as the normalization of the separate accident risk results (i.e. divided by the minimum accident risk observed in the Table), indicating the higher percentage of accident risk in comparison to the minimum accident risk of drivers in Greece. The top part of the Table concerns the detailed four-dimensional fault risk breakdown (per driver's nationality, area type, at or not at junction, lighting conditions), whereas the bottom part concerns the average fault risk corresponding to each particular classification. It should be noted that confidence intervals should be calculated for the fault risk rates; however, as these confidence intervals can be directly derived from the modeling process, they are not presented at this stage.

Table 3 to be inserted here

The accident risk rates of the four drivers' categories show that Greeks have lower accident risk than all foreign drivers. It could be deduced that Greek drivers are by far more familiar with the different complexity of the road infrastructure, which is partly due to the diverse Greek relief and partly due to deficiencies of the road infrastructure itself, and this natural adaptation helps to a better response to accident risk. Among the three categories of foreign drivers the drivers of other nationality (non-Albanian and non-EU) appear to have higher accident risk than the other two categories.

Accident risk for Greek drivers remains lower inside urban areas than the other three categories. All foreign drivers appear to be at increased risk inside urban areas; it is interesting to note that this increased risk is doubled for EU and other nationalities compared to Albanians, however there is no significant difference among the risks of drivers from EU and Albania outside urban areas. It can be assumed that the unfamiliarity of foreign drivers with the road infrastructure leads to a less risk-taking and more conservative driving behavior outside urban areas, such as lower speeds or increased attention and compliance with the road signalization, at least when this is understandable. Drivers with other nationality bear in all cases the highest accident risk.

Some differentiations to the results also occur in the case of accident risk at junctions. Greek drivers have, as expected, the lowest risk but Albanians appear to have better figures than the rest two categories of foreign drivers. Taken that junctions are a sensitive and yet complex part of the road infrastructure, it can be assumed that the seasonality and occasional use of junctions by EU and other nationality foreign drivers renders them more vulnerable to accident risk than Albanians.

The lighting conditions do not seem to affect the accident risk of all the categories of foreign drivers, while Greek drivers remain the ones with the lowest accident risk. An increased risk during the night is only observed for EU nationals. The results of this category do not fully confirm the initial suspicion that the additional difficulty added by night lighting conditions adds to the accident risk of drivers unfamiliar with the road infrastructure.

The above results were further analyzed and interpreted through the development of log-linear models allowing for the investigation of the significance of detailed interactions among variables.

3.2. Combined effects on accident risk

3.2.1. A saturated log-linear model

The first stage of the analysis concerns a preliminary investigation of the significance of various combinations of effects. Therefore, a hierarchical log-linear analysis was applied to the frequencies of accidents, in order to test the saturated design of effects among variables. This approach includes an automatic stepwise backwards elimination of non-significant effects,; allowing for some first insight on the best generating class (highest order significant effects) of the model that would optimally describe the data. Table 4 concerns the results of the investigation on the significance of k-order effects within the saturated model. The following abbreviations are used for the examined variables:

Accident fault (at or not at fault):	guilty	(1,2)
Area type (inside / outside urban area):	in_out	(1,2)
At or not at junction:	junction	(1,2)
Lighting conditions (daylight, night):	light	(1,2)
Nationality (Greek, Albanian, EU national, Other):	nation	(1, 2, 3, 4)

Table 4 to be inserted here

It is obvious that the four- and five-variables combinations are non significant when examining overall effects. In Table 5, the parameter estimates and related significances are presented for the saturated model. Significances of the parameter estimates are obtained by means of Wald tests, i.e. by calculating a Z-value (ratio of a coefficient by its standard error), squaring this value and comparing to a chi square distribution (Agresti, 1996).

The saturated model has generating class (guilty*nation*junction*in_out*nation) and allows no constant term in the model. It is interesting to notice that the combination of accident fault, nationality and junction includes one significant effect. Additionally, there is one significant third-order interaction among nationality, lighting conditions, area type and junction, which, not including the parameter of accident fault, simply indicates a significantly different presence of different nationalities in different road environments. This effect, although statistically significant, is not interesting in the present analysis.

Table 5 to be inserted here

A stepwise backward elimination of non-significant effects was then carried out, in order to identify the generating class of the best-fitting model i.e. the highest k-order effects which are statistically significant. The best model, obtained as a result of 17 steps, had generating class guilty*junction*nation, light*in_out*nation, light*junction, junction*in_out and a likelihood ratio chi-square equal to 27.236, which is non significant for 34 degrees of freedom (probability = 0.788). It is interesting to note that the initially significant third order interaction among nationality and all examined road characteristics was rejected during the stepwise elimination, resulting to a second-order model, which does not present an adequate fit to the data.

3.2.2. A non-saturated log-linear model

On the basis of the above, the second part of the analysis was oriented towards a simpler and more flexible design (non-saturated modeling, allowing a constant term). The modeling was limited to the examination of a second-order design, as the initial investigation provided some indication that one or more three-variable combinations could be significant. Additionally, only the effects that are interesting for the purposes of the present research are examined i.e. effects combining driver nationality and accident fault with single roadway characteristics. In this framework, the hierarchical structure of log-linear models was also respected.

In particular, the examined model has generating class (guilty*nation*junction), (guilty*nation*in_out), (guilty*nation*light), and includes all the related lower-order effects. The parameter estimates and significances for this model are summarized in Table 6.

Table 6 to be inserted here

The non-saturated model presented a very satisfactory overall fit with a likelihood ratio test producing a likelihood ratio chi-square equal to 10,340.77 for 32 residual degrees of freedom, which is highly significant (Washington et al., 2003); therefore the assumption that the examined associations among variables are zero is rejected. This may be attributed to the incorporation of a constant term in the model, as well as the elimination of unnecessary convergence constraints from the model through the non-saturated design. Moreover, the particular model is more adapted to the objectives of the present research.

As far as the various combined effects are concerned, the second-order interaction among accident fault, driver nationality and junction was found to be significant at a 95% confidence level, indicating that the relationship between accident fault risk and driver nationality is significantly different at or not at junction. It should be noted, however, that the second-order interactions among fault risk, nationality and area type, and fault risk, nationality and lighting conditions are significant at a 90% confidence level.

3.2.3. Comparing observed and expected accident fault risk

It should be noted that the parameter estimates of the models are in fact log-odds ratios. Moreover, from the standard errors of these coefficients, one can calculate the related confidence intervals of the log-odds ratios, in order to account for the significance of the comparisons among different categories. For example, the parameters of the interaction among accident fault, nationality and junction indicate that the relative risk of being at fault at junctions to the relative risk of being at fault not at junctions is for Greek drivers exp(-0.371)=0.69, for Albanian drivers exp(-0.279)=0.76 and for EU drivers exp(0.031)=1.03, i.e. Greek drivers are by 31% less likely to provoke an accident at junctions, Albanian drivers are by 24% less likely to provoke an accident at junctions and EU drivers are by 3% more likely to provoke an accident at junctions, in relation to other nationality drivers.

It is important to notice that exactly the same result can be obtained though the standard odds ratios calculations on the observed frequencies. In Table 7, the observed odds ratios are compared to the expected odds ratios, as derived from the models parameter estimates. As expected, the odds ratios of the saturated model present in some cases significant differences from the observed odds, whereas there is very little difference between the respective observed and expected odds ratios as far as the non-saturated model is concerned.

Table 7 to be inserted here

It should be also noted that the above odds ratios can be obtained when normalizing appropriately the analytical risk rates of Table 3. In particular, Table 3 is a simple yet comprehensive presentation of accident risk rates, through the direct calculation of "guilty to not guilty" odds ratios. The relative risk ratios are presented in relation to the minimum estimated risk, in order to provide the overall variation of fault risk. On the other hand, the odds ratios obtained from the models concern particular variable groups in each case, as the modeling process aimed at identifying the interactions within these particular groups. Consequently, the relative risk rates are derived from a more complex calculation, as the "guilty to not guilty" rates are presented in relation to the risk of one category of the roadway environment variable and one category of the nationality variable at the same time. Obviously, no inconsistency among the results obtained by the two approaches is observed.

4. Discussion

In the present research, a log-linear analysis was used to investigate the relative accident fault risk distribution among different driver nationality categories. The analysis was focused on the examination of the effect of roadway environment. An initial detailed relative risk classification was carried out, including examination of single, as well as combined roadway environment effects on the fault risk of various nationalities, resulting to a five-dimensional risk Table including summary three-dimension average classifications, allowing for the related comparisons. This approach is a simple yet comprehensive way of presenting multi-dimensional risk classifications within induced exposure assumptions, as long as the exclusively relative comparability of the risk rates is taken into account. It should be noted that sufficient preliminary analysis was carried out to allow for the adoption of the "innocent" drivers' distribution as a measure of exposure by nationality.

Different structural designs of log-linear modeling were also tested. A second-order non-saturated model design was found to have a very satisfactory performance in the description of the structural relationships between variables, whereas the basic fourth-order saturated model design presented a poor fit. It was thereby indicated that a parsimonious design is more flexible and adequate for predicting the log-frequencies related to a multi-dimensional risk Table. On the contrary, the saturated design imposes design and convergence constraints that may compromise its performance, especially when one is interested in particular structural relationships within variables' groups.

The use of log-linear analysis on multi-dimensional Tables also allows for an indirect validation of the significance of the relative risk rates. Additionally, the decomposition of odds ratios produced by the log-linear models allows for better comprehension of the various levels of detail of the risk rates that can be produced from the combination of many variables within the induced exposure technique. In the present research, no systematic inconsistencies were identified among observed and expected risks, allowing the assessment of disaggregate risk obtained by the induced exposure method according to the significances of the parameters of the log-linear models.

In general the data analyzed indicate that there is indeed an increased accident risk for drivers of foreign nationality in Greece. It was deduced that roadway characteristics do not influence accident risk of foreign or native drivers in a multiplicative way (no interaction of accident fault risk, driver nationality and more than one roadway parameters was found to be significant). However, particular road characteristics were found to significantly differentiate the risk of the various nationalities examined. In particular, inhabited areas and junctions are two road infrastructure factors that appear to influence the accident risk. On the contrary lighting conditions and non-inhabited areas do not seem to systematically differentiate accident risks of foreign drivers. This may be attributed to the fact that urban areas and junctions require a more demanding driving behavior, namely a combination of decisions under more complex traffic conditions and more traffic rules. It is noted that Albanians (i.e. immigrant permanent residents), who are more familiar with the road environment and the traffic rules appear to be less vulnerable than EU and other nationality categories corresponding to tourists or other occasional users of the road network.

The above findings also confirm that different types of foreign drivers present a significantly different accident risk, it is therefore necessary to promote appropriate targeted interventions, better adapted to the needs and issues of each category. For instance, for the improvement of the road safety of immigrant permanent residents (in the present study represented by Albanian nationals) might also include some training on the national rules, traffic and road signals and driving practices. Accordingly, measures addressed to tourists and visitors (in this study represented by EU nationals) should focus on improving the road infrastructure, signing and signalization to provide a more self-explaining as well as forgiving road environment, especially in and around the most popular tourist destinations, as well as in the entire main interurban road network.

This research has also demonstrated that an efficient upgrade in the design and signalization of junctions would be an important step in improving the road safety of all foreign drivers. Obviously, native road users would benefit from all these interventions as well.

From the above analysis it can be said that foreign drivers are unfamiliar with the existing road environment, which makes them more vulnerable than the natives in a foreign country. The lack of understanding of the particular roadway and traffic characteristics in a foreign country plays an important role, and further research is required to study this aspect.

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Table1. Number of foreign persons killed and accidents with foreign driver's involvement in Greece (1985 - 2000)

Number of foreign persons killed			Road user type (%)			Age (%)		
Year	Total	%	driver	passenger	pedestrian	<35	35-54	>55
1985	68	3.0	50.0	41.2	8.8	63.2	23.5	13.2
1986	58	2.6	46.6	32.8	20.7	55.2	27.6	17.2
1987	88	3.9	51.1	36.4	12.5	69.3	20.5	10.2
1988	71	3.2	50.7	26.8	22.5	62.0	28.2	9.9
1989	67	3.0	53.7	29.9	16.4	58.2	32.8	9.0
1990	71	3.2	47.9	33.8	18.3	57.7	28.2	14.1
1991	98	4.4	42.9	31.6	25.5	66.3	27.6	6.1
1992	128	5.7	41.4	28.9	29.7	60.2	31.3	8.6
1993	147	6.6	49.0	30.6	20.4	66.7	23.8	9.5
1994	149	6.7	49.0	23.5	27.5	67.1	20.8	12.1
1995	155	6.9	49.7	28.4	21.9	69.0	21.3	9.7
1996	182	8.1	52.2	31.3	16.5	65.4	26.4	8.2
1997	200	8.9	54.5	25.5	20.0	68.0	21.5	10.5
1998	219	9.8	45.7	29.2	25.1	63.1	26.7	10.1
1999	277	12.4	44.8	37.9	17.3	64.4	26.2	9.5
2000	259	11.6	49.8	38.2	12.0	63.7	28.9	7.4
Total	**2,237**	**100.0**	**48.5**	**31.7**	**19.7**	**64.5**	**25.7**	**9.8**

Accidents with foreign drivers			Area type		Lighting conditions		Junction	
Year	Total	%	inside	outside	day	night	yes	no
1985	927	3.9	57.0	43.0	63.8	36.2	-	-
1986	806	3.4	47.0	53.0	68.2	31.8	-	-
1987	876	3.7	47.4	52.6	65.4	34.6	-	-
1988	913	3.9	50.9	49.1	65.2	34.8	-	-
1989	944	4.0	48.8	51.2	64.4	35.6	-	-
1990	889	3.8	47.8	52.2	64.5	35.5	-	-
1991	1,015	4.3	55.7	44.3	63.8	36.2	-	-
1992	1,224	5.2	55.8	44.2	62.8	37.2	-	-
1993	1,246	5.3	55.6	44.4	62.7	37.3	-	-
1994	1,357	5.7	57.6	42.4	60.2	39.8	-	-
1995	1,462	6.2	56.2	43.8	61.4	38.6	-	-
1996	1,736	7.3	60.4	39.6	59.3	40.7	42.9	57.1
1997	1,904	8.0	53.6	46.4	60.1	39.9	43.5	56.5
1998	2,477	10.5	61.1	38.9	59.7	40.3	46.5	53.5
1999	2,948	12.4	64.7	35.3	58.1	41.9	48.6	51.4
2000	2,960	12.5	67.7	32.3	59.6	40.4	51.7	48.3
Total	**23,684**	**100.0**	**57.9**	**42.1**	**61.4**	**38.6**	**47.3**	**52.7**

Table 2. 'Innocent' drivers' distribution by nationality for different nationalities of 'at-fault' driver

	At-fault driver's nationality		
Innocent drivers' distribution (%)	Greek	Albanian	EU-15
Greek	95.65	94.09	87.83
Albanian	0.97	1.08	7.30
EU-15	1.81	3.36	2.43
Other	1.56	1.48	2.43
Total	100.00	100.00	100.00

Table 3. Relative accident risk rates per drivers' nationality and road characteristics

Junction	Area type	Lighting Conditions	Driver's Nationality: Greece	Albania	EU	Other
Yes	Inside Urban Area	Daylight	1.08	1.50	2.29	2.34
Yes	Inside Urban Area	Night	1.08	1.52	2.06	2.13
Yes	Outside Urban Area	Daylight	1.09	1.04	1.26	2.72
Yes	Outside Urban Area	Night	1.08	1.48	1.48	2.22
No	Inside Urban Area	Daylight	1.10	1.30	1.33	1.46
No	Inside Urban Area	Night	1.10	1.33	1.60	1.20
No	Outside Urban Area	Daylight	1.08	1.73	1.10	1.87
No	Outside Urban Area	Night	1.09	1.00	1.80	1.43
Junction						
Yes			1.08	1.46	1.88	2.29
No			1.09	1.33	1.27	1.59
	Area Type					
	Inside Urban Area		1.08	1.46	1.92	1.96
	Outside Urban Area		1.09	1.30	1.25	1.88
		Lighting Conditions				
		Daylight	1.08	1.46	1.40	2.05
		Night	1.09	1.35	1.80	1.75
Total			1.08	1.41	1.50	1.93

Table 4. Significance of K-order effects among variables (accident fault, nationality, area type, junction, lighting conditions)

Design: Saturated (fault*nation*in_out*junction*light)

Tests that K- and lower-order effects are zero

K	Degrees of freedom	Chi-square	Probability
5	3	1.703	0.636
4	16	14.060	0.594
3	38	48.414	0.120
2	56	10,846.717	0.000
1	63	141,578.289	0.000

Table 5. Parameter estimates and significances for the saturated log-linear model

Design: Saturated
Model: Poisson

Parameter	Estimate	Std. Error	Z-value	Significance
[guilty = 1]	-0.210	0.019	-11.073	0.000 *
[light = 1]	0.237	0.019	12.505	1.000
[junction = 1]	-0.016	0.019	-0.840	0.200
[in_out = 1]	0.215	0.019	11.324	1.000
[nation = 1]	3.026	0.019	155.919	1.000
[nation = 2]	-0.971	0.036	-27.244	0.000 *
[nation = 3]	-1.246	0.040	-31.465	0.000 *
[guilty = 1] * [light = 1]	0.001	0.019	0.068	0.527
[guilty = 1] * [junction = 1]	0.037	0.019	1.971	0.976
[guilty = 1] * [in_out = 1]	0.016	0.019	0.820	0.794
[guilty = 1] * [nation = 1]	-0.142	0.019	-7.314	0.000 *
[guilty = 1] * [nation = 2]	-0.030	0.036	-0.855	0.196
[guilty = 1] * [nation = 3]	0.046	0.040	1.162	0.877
[light = 1] * [junction = 1]	0.006	0.019	0.316	0.624
[light = 1] * [in_out = 1]	-0.095	0.019	-5.031	0.000 *
[light = 1] * [nation = 1]	-0.027	0.019	-1.411	0.079
[light = 1] * [nation = 2]	-0.119	0.036	-3.328	0.000 *
[light = 1] * [nation = 3]	0.200	0.040	5.064	1.000
[junction = 1] * [in_out = 1]	0.500	0.019	26.355	1.000
[junction = 1] * [nation = 1]	0.056	0.019	2.883	0.998
[junction = 1] * [nation = 2]	0.070	0.036	1.971	0.976
[junction = 1] * [nation = 3]	-0.123	0.040	-3.109	0.001 *
[in_out = 1] * [nation = 1]	0.124	0.019	6.396	1.000
[in_out = 1] * [nation = 2]	0.155	0.036	4.354	1.000
[in_out = 1] * [nation = 3]	-0.246	0.040	-6.225	0.000 *
[guilty = 1] * [light = 1] * [junction = 1]	-0.006	0.019	-0.338	0.368
[guilty = 1] * [light = 1] * [in_out = 1]	0.001	0.019	0.050	0.520
[guilty = 1] * [light = 1] * [nation = 1]	-0.003	0.019	-0.166	0.434
[guilty = 1] * [light = 1] * [nation = 2]	0.009	0.036	0.262	0.603
[guilty = 1] * [light = 1] * [nation = 3]	-0.049	0.040	-1.238	0.108
[guilty = 1] * [junction = 1] * [in_out = 1]	0.018	0.019	0.949	0.829
[guilty = 1] * [junction = 1] * [nation = 1]	-0.044	0.019	-2.276	0.011 *
[guilty = 1] * [junction = 1] * [nation = 2]	-0.033	0.036	-0.935	0.175
[guilty = 1] * [junction = 1] * [nation = 3]	0.005	0.040	0.139	0.555
[guilty = 1] * [in_out = 1] * [nation = 1]	-0.011	0.019	-0.573	0.283
[guilty = 1] * [in_out = 1] * [nation = 2]	0.013	0.036	0.361	0.641
[guilty = 1] * [in_out = 1] * [nation = 3]	0.049	0.040	1.236	0.892
[light = 1] * [junction = 1] * [in_out = 1]	0.015	0.019	0.780	0.782
[light = 1] * [junction = 1] * [nation = 1]	0.005	0.019	0.261	0.603
[light = 1] * [junction = 1] * [nation = 2]	0.024	0.036	0.664	0.747
[light = 1] * [junction = 1] * [nation = 3]	0.017	0.040	0.432	0.667
[light = 1] * [in_out = 1] * [nation = 1]	-0.006	0.019	-0.297	0.383
[light = 1] * [in_out = 1] * [nation = 2]	0.066	0.036	1.864	0.969
[light = 1] * [in_out = 1] * [nation = 3]	-0.048	0.040	-1.215	0.112
[junction = 1] * [in_out = 1] * [nation = 1]	-0.011	0.019	-0.583	0.280
[junction = 1] * [in_out = 1] * [nation = 2]	0.004	0.036	0.107	0.543
[junction = 1] * [in_out = 1] * [nation = 3]	-0.019	0.040	-0.492	0.311
[guilty = 1] * [light = 1] * [junction = 1] * [in_out = 1]	0.012	0.019	0.653	0.743
[guilty = 1] * [light = 1] * [junction = 1] * [nation = 1]	0.008	0.019	0.415	0.661
[guilty = 1] * [light = 1] * [junction = 1] * [nation = 2]	-0.050	0.036	-1.396	0.081
[guilty = 1] * [light = 1] * [junction = 1] * [nation = 3]	0.045	0.040	1.146	0.874
[guilty = 1] * [light = 1] * [in_out = 1] * [nation = 1]	-0.003	0.019	-0.160	0.436
[guilty = 1] * [light = 1] * [in_out = 1] * [nation = 2]	-0.015	0.036	-0.423	0.336
[guilty = 1] * [light = 1] * [in_out = 1] * [nation = 3]	0.033	0.040	0.837	0.799
[guilty = 1] * [junction = 1] * [in_out = 1] * [nation = 1]	-0.022	0.019	-1.142	0.127
[guilty = 1] * [junction = 1] * [in_out = 1] * [nation = 2]	0.000	0.036	-0.010	0.496
[guilty = 1] * [junction = 1] * [in_out = 1] * [nation = 3]	0.031	0.040	0.772	0.780
[light = 1] * [junction = 1] * [in_out = 1] * [nation = 1]	-0.012	0.019	-0.633	0.263
[light = 1] * [junction = 1] * [in_out = 1] * [nation = 2]	-0.063	0.036	-1.766	0.039 *
[light = 1] * [junction = 1] * [in_out = 1] * [nation = 3]	0.019	0.040	0.474	0.682
[guilty = 1] * [light = 1] * [junction = 1] * [in_out = 1] * [nation = 1]	-0.013	0.019	-0.689	0.245
[guilty = 1] * [light = 1] * [junction = 1] * [in_out = 1] * [nation = 2]	0.043	0.036	1.196	0.884
[guilty = 1] * [light = 1] * [junction = 1] * [in_out = 1] * [nation = 3]	-0.014	0.040	-0.352	0.362

** indicates a significant effect*

Table 6. Parameter estimates and significances for the non-saturated second-order log-linear model

Design: Constant + guilty + nation + in_out + light + junction + guilty*in_out + guilty*junction + guilty*light + guilty*nation + in_out*nation + junction*nation + light*nation + guilty*nation*in_out + guilty*nation*light + guilty*nation*junction
Model: Poisson

Parameter	Estimate	Std. Error	Z-value	Significance
Constant	3.895	0.094	41.296	0.000 *
[guilty = 1]	-0.428	0.143	-2.987	0.003 *
[in_out = 1]	0.272	0.089	3.066	0.002 *
[junction = 1]	-0.085	0.088	-0.966	0.334
[light = 1]	0.319	0.089	3.588	0.000 *
[nation = 1]	3.625	0.095	38.055	0.000 *
[nation = 2]	-0.433	0.141	-3.083	0.002 *
[nation = 3]	-0.196	0.147	-1.331	0.183
[guilty = 1] * [in_out = 1]	0.036	0.130	0.280	0.779
[guilty = 1] * [junction = 1]	0.348	0.129	2.689	0.007 *
[guilty = 1] * [light = 1]	0.146	0.131	1.108	0.268
[guilty = 1] * [nation = 1]	-0.262	0.145	-1.806	0.071
[guilty = 1] * [nation = 2]	-0.188	0.223	-0.841	0.400
[guilty = 1] * [nation = 3]	-0.106	0.227	-0.467	0.641
[in_out = 1] * [nation = 1]	0.400	0.089	4.471	0.000 *
[in_out = 1] * [nation = 2]	0.450	0.128	3.502	0.000 *
[in_out = 1] * [nation = 3]	-0.791	0.136	-5.813	0.000 *
[junction = 1] * [nation = 1]	0.461	0.089	5.198	0.000 *
[junction = 1] * [nation = 2]	0.494	0.125	3.944	0.000 *
[junction = 1] * [nation = 3]	-0.455	0.136	-3.353	0.001 *
[light = 1] * [nation = 1]	0.043	0.090	0.485	0.628
[light = 1] * [nation = 2]	-0.175	0.125	-1.399	0.162
[light = 1] * [nation = 3]	0.760	0.145	5.234	0.000 *
[guilty = 1] * [in_out = 1] * [nation = 1]	-0.032	0.132	-0.242	0.809
[guilty = 1] * [in_out = 1] * [nation = 2]	0.090	0.199	0.454	0.650
[guilty = 1] * [in_out = 1] * [nation = 3]	0.395	0.205	1.921	0.055
[guilty = 1] * [junction = 1] * [nation = 1]	-0.371	0.131	-2.836	0.005 *
[guilty = 1] * [junction = 1] * [nation = 2]	-0.279	0.193	-1.446	0.148
[guilty = 1] * [junction = 1] * [nation = 3]	0.031	0.205	0.151	0.880
[guilty = 1] * [light = 1] * [nation = 1]	-0.158	0.133	-1.187	0.235
[guilty = 1] * [light = 1] * [nation = 2]	-0.070	0.192	-0.364	0.716
[guilty = 1] * [light = 1] * [nation = 3]	-0.408	0.218	-1.872	0.061

**indicates a significant effect*

Goodness-of-Fit	Value	df	Significance
Likelihood Ratio	10,340.77	32	0.000

Table 7. Observed and expected odds-ratios of fault risk, nationality and roadway characteristics

	Observed odds ratio	Expected odds ratios	
		Saturated Model	Non-saturated Model
[guilty = 1] * [in_out = 1] * [nation = 1]	0.961	0.989	0.969
[guilty = 1] * [in_out = 1] * [nation = 2]	1.082	1.013	1.094
[guilty = 1] * [in_out = 1] * [nation = 3]	1.473	1.050	1.484
[guilty = 1] * [in_out = 1] * [nation = 4]	1.000	1.000	1.000
[guilty = 1] * [junction = 1] * [nation = 1]	0.684	0.957	0.690
[guilty = 1] * [junction = 1] * [nation = 2]	0.756	0.968	0.757
[guilty = 1] * [junction = 1] * [nation = 3]	1.024	1.005	1.031
[guilty = 1] * [junction = 1] * [nation = 4]	1.000	1.000	1.000
[guilty = 1] * [light = 1] * [nation = 1]	0.848	0.997	0.854
[guilty = 1] * [light = 1] * [nation = 2]	0.921	1.009	0.932
[guilty = 1] * [light = 1] * [nation = 3]	0.660	0.952	0.665
[guilty = 1] * [light = 1] * [nation = 4]	1.000	1.000	1.000
[guilty = 1] * [nation = 1]	0.563	0.868	0.770
[guilty = 1] * [nation = 2]	0.730	0.970	0.829
[guilty = 1] * [nation = 3]	0.779	1.047	0.899
[guilty = 1] * [nation = 4]	1.000	1.000	1.000